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Japanese Patent Filing Date:

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Washington, D.C. 20231

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(2) that he translated the above-identified Japanese Application from Japanese to English;

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July 29, 2005
Date

Tatsuki Nakayama
Signature

Tatsuki Nakayama
Typed name

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Applicant(s) :	NEC Electronics Corporation

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Commissioner,
Patent Office Yasuo IMAI

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[DOCUMENT NAME] Specification

[TITLE OF THE INVENTION] CHEMICAL MECHANICAL POLISHING METHOD

[SCOPE OF THE INVENTION]

[Claim 1]

A chemical mechanical polishing method, in which a low-permittivity layer, including methyl radicals and exhibiting a dielectric constant of less than 3.0, is polished with an abrasive liquid including a hydroxyl group.

[Claim 2]

A chemical mechanical polishing method as set forth in claim 1, wherein said low-permittivity layer comprises either a methyl silsesquioxane layer or a SiCOH layer which is formed on a silicon wafer.

[Claim 3]

A chemical mechanical polishing method as set forth in claim 1, wherein said abrasive liquid exhibits an acidity of pH3 ~ pH6.

[Claim 4]

A chemical mechanical polishing method as set forth in claim 1, wherein said abrasive liquid includes at least one aluminum compound which is aluminum oxide.

[Claim 5]

A chemical mechanical polishing method, in which a low-permittivity layer, formed on a silicon wafer, including methyl radicals, and exhibiting a dielectric constant of less than 3.0, is polished with an abrasive liquid including a hydroxyl group, and said silicon wafer is subjected to a washing process after the polishing process, with a surface of said low-permittivity layer being drenched with said abrasive liquid without being completely dried.

[Claim 6]

A chemical mechanical polishing method as set forth in claim 5, wherein said washing process comprises squirting and

washing said silicon wafer with oxalic acid or dilute hydrofluoric acid, and then squirting and washing said silicon wafer with pure water.

[DETAILED EXPLANATION OF THE INVENTION]

[0001]

[Field Of The Invention]

The present invention relates to a chemical mechanical polishing (CMP) method. More particularly, the invention relates to method for polishing a surface of a wafer, having semiconductor elements formed therein, to thereby planarize the same, and further relates to a method for washing the wafer after the polishing process.

[0002]

In production of semiconductor elements, a so-called multi-layered wiring structure is frequently constructed. In this multi-layered wiring structure, a plurality of lower-layer wiring-lines are formed on an insulating layer, formed on a semiconductor substrate, so as to be adjacent to each other; an insulating interlayer comprising an oxide layer is formed between the lower-layer wiring-lines and over the lower-layer wiring-lines; and a plurality of upper-layer wiring-lines are formed on the insulating interlayer. In this case, due to there being offsets between the lower-layer wiring-lines, the insulating interlayer formed thereon exhibits unevenness. When a plurality of upper-layer wiring-line are further formed on the insulating interlayer exhibiting the unevenness, it may cause various problems, e.g. there may be a case where it is impossible to carry out the formation of the upper-layer wiring-lines at desirable dimensions, or where it is impossible to carry out the formation of a pattern itself of the upper-layer wiring-lines. Thus, in general, the insulating interlayer is polished and planarized, and the upper-layer wiring-lines are formed thereon.

[0003]

In Fig. 1, a schematic arrangement of a CMP apparatus, which is conventionally and generally used to planarize an insulating interlay or the like, is illustrated in a side view. On a polishing table 11, an abrasive pad 12 is adhered. Also, a carrier 13 has a wafer-holding pad 14 for holding a wafer 16 in a manner of vacuum suction or the like. A nozzle 15 is provided to pour out an abrasive liquid. In a polishing process, while a constant volume of the abrasive liquid is continuously poured out of the nozzle 15 over the abrasive pad 12 at a central area thereof if possible, the polishing table 11 and the carrier 13 are rotated in the same rotational direction with respect to each other, and then the wafer 16 is pressed against the abrasive pad 12 by the carrier 13, to thereby polish the wafer 16. For the abrasive liquid, a water, including abrasive material, for example, fumed silica, as a main component, is used. In general, this abrasive liquid includes no additive except for the abrasive material. A pH of the this abrasive liquid exhibits either neutrality or weak alkalinity.

[0004]

Next, in Figs. 2 and 3, schematic arrangements of washing apparatuses for respectively washing and rinsing the polished wafer with chemical liquid and pure water are in perspective views. In Fig. 2, respective nozzles 22 squirt the chemical liquids over both the front and rear surfaces of the wafer 16, and cylindrical (roll-like) brushes 21 are reversely rotated with respect to each other around a center axis crossing the centers of the cylindrical surfaces of the cylindrical brushes 21. Then, the wafer 16, polished wafer by the polishing apparatus of Fig. 1, is pinched by the two brushes 21, and is moved through a nip between in a pushing direction, in which the wafer is pushed out by both the rotating brushes, at a speed slower than a speed at which the wafer is pushed out by both the rotating brushes. Thus, by these brushes, foreign objects, which may be penetrated

in grooves or the like included in patterns formed on the wafer, can be even removed therefrom. The chemical liquid is an organic chemical liquid, such as oxalic acid ($C_2H_2O_4$), dilute hydrofluoric acid (DHF) having a concentration of approximately 0.5%, or the like. Any one of these chemical liquids may have a low concentration. By using one of these chemical liquids, metal components left on the wafer are changed to complex compounds, and thus it is possible to make adhesive force to the wafer small. In general, after the aforesaid oxide layer is polished by the CMP, the DHF is used in the washing of the polished oxide layer, and, after coppers (Cu) or tungstens (W), which are buried in trenches formed in an insulating layer, are polished by the CMP, the oxalic acid is used in the washing of the polished coppers or tungstens. Then, the wafer 16 is transferred to a washing table 31 of Fig. 3, and is securely vacuum-sucked thereto. While pure water is poured out of a nozzle 32 over the wafer, the table is rotated to thereby wash the chemical liquid together with the foreign objects out of the wafer 16. Finally, the pour of the pure water is stopped, and the table is rotated at a high speed to thereby remove the water from the wafer, resulting in completion of the washing process.

[Patent Document 1]

USP 6423630

[0005]

[Problems To Be Resolved By the Invention]

By the way, with the recent advance of miniaturization of semiconductor devices, spaces between the wiring-lines become closer to each other. On the other hand, in general, the oxide layer is used as an insulating material between the wiring-lines. Due to these matters, a value of a parasitic capacitance, which is unintentionally produced between the wiring-lines, becomes larger. Thus, the large value of the parasitic capacitance results in considerable delay of signal transmission in the

wiring-lines, and this problem cannot be neglected in a design of integrated circuits.

[0006]

In order to solve this signal transmission delay problem, as the insulating material between the wiring-lines, an insulating layer, having a smaller dielectric constant than that of the oxide layer, is used. By using this low dielectric constant insulating layer or low dielectric constant insulating interlayer (which is called a low-k layer hereinafter), the value of the parasitic capacitance produced between the wiring-lines is made lower in comparison with the case where the conventional oxide layer is used, so that it is possible to suppress the delay of signal transmission. When the CMP of the insulating interlayer comprising the low-k layer as the insulating layer between the wiring-lines is carried out, it is disclosed in USP 6423630, column 6, lines 13 ~ 29 that a slurry for polishing the oxide layer is utilized as it stands. Note, "an oxide slurry" is a technical term which means a slurry for polishing the oxide layer.

[0007]

A first problem is that a sufficient polishing rate cannot be obtained when polishing the low-k layer with an abrasive liquid which is conventionally used for the CMP of the oxide layer. Respective tests for polishing a plasma-formed silicon dioxide layer (P-SiO_2 layer) and a low-k layer were carried out. The test results are shown as differences of the polishing rates in Fig. 4. As is apparent from this drawing, as for the P-SiO_2 layer, a polishing rate of 3,000 Å/min was obtained, but, as for the low-k layer or SiCOH layer, only a polishing rate of approximately 100 Å/min was obtained. As for the low-k layer, it takes too much polishing time when using the conventional abrasive liquid, which cannot be brought into practice, resulting in an increase in a production cost. Note, as a sample, an 8-inch

silicon wafer (SW), having a 4,000Å-thickness SiCOH layer (k=2.9) formed by a CVD process, was used. Also, each of the polishing processes was carried out by the apparatus of Fig. 1 under the conditions that the wafer is pressed against the abrasive pad by the carrier at a low polishing pressure of 3 ~ 5 psi, and that the carrier and the polishing table are rotated in the same rotational direction at a low rotational speed of 28 ~ 36 rpm. Herein, the pressure and the rotational speed are merely shown by way of example, because an angular speeds at each of locations to be polished on the wafer is varied in accordance with a size of the wafer to be polished and a radial movement manner of the rotating carrier on the polishing table. In Fig. 4, the polishing conditions of the P-SiO_2 layer were the same as those of the low-k layer. Further, although a polishing process of the low-k layer was carried out under a high polishing pressure of 8 psi, there was not a large difference in comparison of the case of the low polishing pressure.

[0008]

A second problem is that, although each of the wafer is washed after the polishing process, removal of grounds, abrasive substances, foreign substances and so on cannot be carried out, so the these substances are left on the wafer after the washing process. An amount of the residual substances on each of the wafers before the polishing process and an amount of the residual substances on each of the wafers after the polishing and washing processes were inspected, and testes were carried out to measure how many an amount of the residual substances is increased after the polishing and washing processes in comparison with the amount of the residual substances before the polishing process. The test results are shown in Fig. 5. As is apparent from this drawing, as for the low-k layer, it is found that the increase of the amount of the residual substances is considerably large in comparison with the conventional P-SiO_2

layer. When the production is carried out, using the wafer having the large amount of the residual substances, production defects may be involved, a yield rate of production may become lower, and a production cost may become higher. Note, in the foreign-substance inspection carried out after the washing process, the wafer, rinsed with chemical liquid and pure water, were used. A number of the foreign substances were measured by successively counting the foreign substances having diameters of more than 0.2 μm every a diameter by using a foreign-substance inspection apparatus.

[0009]

An object of the present invention is to improve a polishing rate of a low-k layer in comparison with the prior art. Further, an object of the present invention is to suppress an amount of residual substances on a polished and washed low-k layer so as to be equivalent to or less than an amount of residual substances on a polished and washed oxide layer.

[0010]

[Means For Solving The Problems] In order to solve the above-mentioned problems,

(1) A chemical mechanical polishing method according to the present invention is characterized by the fact that a low-permittivity layer, including methyl radicals and exhibiting a dielectric constant of less than 3.0, is polished with an abrasive liquid including a hydroxyl group.

(2) The chemical mechanical polishing method as set forth in (1) is characterized by the fact that said low-permittivity layer comprises either a methyl silsesquioxane layer or a SiCOH layer which is formed on a silicon wafer.

(3) The chemical mechanical polishing method as set forth in (1) is characterized by the fact that said abrasive liquid exhibits an acidity of pH3 ~ pH6.

(4) The chemical mechanical polishing method as set forth

in (1) is characterized by the fact that said abrasive liquid includes at least one aluminum compound of 0.001 ~ 2 wt%, which is aluminum oxide.

(5) A chemical mechanical polishing method according to the present invention is characterized by the facts that a low-permittivity layer, formed on a silicon wafer, including methyl radicals, and exhibiting a dielectric constant of less than 3.0, is polished with an abrasive liquid including a hydroxyl group, and that said silicon wafer is subjected to a washing process after the polishing process, with a surface of said low-permittivity layer being drenched with said abrasive liquid without being completely dried.

(6) The chemical mechanical polishing method as set forth in (5) is characterized by the fact that said washing process comprises squirting and washing said silicon wafer with oxalic acid or dilute hydrofluoric acid, and then squirting and washing said silicon wafer with pure water.

[0011]

[Mode of Carrying Out The Invention] For a polishing apparatus and a washing apparatus used in the present invention, it is possible to utilize the same ones as explained with reference to Figs. 1, 2 and 3 for the prior arts.

[0012]

By the way, as the low-k layer, for example, there are a methyl silsesquioxane layer (which is referred to as an MSQ layer hereinafter), a SiCOH layer or the like. As cause that it is difficult to polish the low-k layers with a polishing liquid used for a CMP operation of an oxide layer, it is pointed out that a surfaces of the low-k layer exhibits a hydrophobic nature due to the fact that methyl radicals (CH_3) are included in the low-k layer. Thus, the conventional polishing liquid containing water as a major component is repelled from the surface of the low-k layer. For this reason, it is considered that, in the

conventional polishing liquid used for the CMP operation of the oxide layer, the polishing liquid is repelled at the surface of the low-k layer, so that a major part of the abrasive material included in the polishing liquid flows out without being in contact with the layer surface. This causes considerable decline in a polishing rate when conventionally polishing the low-k layer, resulting in the processing rate which is unacceptable for a usual use.

[0013]

Therefore, an abrasive liquid according to the present invention includes abrasive material such as colloidal silica as a main component contained in a water, and at least one kind of aluminum compound, which is aluminum oxide, is further added to the abrasive liquid as an additive. By y this, it is possible to carry out the polishing process with the OH-groups included in the aluminum oxide being always adhered to the methyl radicals on the surface of the low-k layer which is the wafer surface, during the polishing process. Like this, the surface of the low-k layer in which the OH-groups are adhered to the methyl radicals is changed from the hydrophobic surface to the hydrophilic surface. Thus, the abrasive liquid cannot be repelled from the surface of the low-k layer, and a major portion of the abrasive material included in the abrasive liquid is in contact with the layer surface, so that it is possible to considerably improve the polishing rate.

[0014]

However, in a case where the aluminum oxide is merely added to the abrasive liquid, another problem occurs. In particular, when the abrasive liquid exhibits alkalinity, there is a possibility that the low-k layer is decomposed. In the low-k layer which is subjected to the decomposition, the compositions are separated, and thus there may be a case where the low-k layer cannot serve as a proper insulating layer.

Therefore, according to the present invention, an additive is added to the abrasive liquid so that it exhibits an acidity of pH3 ~ pH6. On the other hand, since addition of a strong acidity to the abrasive liquid involves risks, and since it is troublesome to handle the abrasive liquid in production of semiconductor devices, it is desirable to give an acidity of at least pH3 to the abrasive liquid. Thus, an aluminum compound, which is aluminum oxide, falling within a range of 0.001 ~ 2 wt% is added to the abrasive liquid, and an additive is added to the abrasive liquid so that it exhibits an acidity falling within a range of pH3 ~ pH6. Note, the colloidal silica, which is the abrasive material, is included in the abrasive liquid at a density of 20 wt%. Also, by adding KOH to the abrasive liquid in place of the aluminum compound which is the oxide, it is possible to improve the polishing rate. Further, practically, it is more preferable to set the acidity of the abrasive liquid within a range of pH3.4 ~ 4.4 for stability of production. It is possible to substitute fumed silica for the same abrasive material as used in the conventional abrasive liquid.

[0015]

By using this abrasive liquid, the polishing process was carried out under the same conditions as in the conventional polishing process. Namely, an 8-inch silicon wafer, having a 4,000Å-thickness SiCOH layer (k=2.9) formed by a CVD process, was used as a sample, and was polished by the apparatus of Fig. 1 at the low polishing pressure of 3 ~ 5 psi and the low rotational speed of 28 ~ 36 rpm. The abrasive liquid was continuously fed to the wafer at 150 ml/min during the polishing process. The polishing results are shown in Fig. 4. Although only the polishing rate of approximately 100 Å/min was obtained when the low-k layer or SiCOH layer was polished with the conventional abrasive liquid, a polishing rate of approximately 1,200 Å/min, which can be brought into practice, can be obtained by merely

using the abrasive liquid according to the present invention. Note, the low-k layer is more fragile in comparison with the P-SiO_2 layer. Thus, when the polishing conditions are determined, the determination of the polishing conditions has to be carried out so that abrasions, called scratches, hardly occur over the wafer surface during the polishing process. In Fig. 4, in the present invention, the same low polishing pressure and low rotational speed as in the conventional case were used. This is a condition in which the occurrence of the scratches upon polishing the low-k layer with the abrasive liquid according to the present invention is taken into account. Also, if the occurrence of the scratches is neglected in polishing the low-k layer with the abrasive liquid, it is possible to raise the polishing rate by increasing the flow rate of the abrasive liquid, the polishing pressure or the rotational speed. However, in the conventional abrasive liquid, although the flow rate of the abrasive liquid, the polishing pressure or the rotational speed is increased, it is impossible to raise the abrasive rate of the low-k layer.

[0016]

Next, a washing process of the aforesaid polished wafer is carried out with a chemical liquid by using the washing apparatus of Fig. 2. Conventionally, after the polishing process, the surface of the low-k layer, which is exposed on the wafer, exhibits the hydrophobic nature due to the methyl radicals on the surface of the low-k layer. Therefore, the washing liquid, a major component of which is water, is repelled from the surface of the low-k layer. Thus, it is considered that the conventional washing liquid, which is used in the washing process after the CMP process of the oxide layer, is repelled from the surface of the low-k layer, so that a major part of the chemical liquid included in the washing liquid flows out of the layer surface without being in contact with the layer

surface. This is because an amount of the residual foreign substances is large, which is unacceptable for a usual use, after the polished low-k surface is washed. Thus, according to the present invention, the washing process of the polished wafer surface is carried out using the chemical liquid, with the abrasive liquid used in the polishing process of the present invention being left on the wafer surface, without completely drying the polished wafer surface. The surface of the polished low-k layer still exhibits the hydrophilic nature due to the polishing liquid left thereon after the polishing process. In this state, when the washing process is carried out, the chemical liquid is in contact with the surface of the low-k layer, so that the foreign substances can be easily removed. Another conventional chemical liquid, another conventional washing apparatus and another conventional washing method may be used as they stand. After the washing process is carried out with the chemical liquid, a washing process is carried out with a pure water of Fig. 3 in the same manner as in the conventional case. An amount of the foreign substances before the aforesaid polishing process and an amount of the foreign substances after the aforesaid washing process were inspected in the same foreign-substance inspection method as in the conventional case, and an increase of the foreign substances was measured. The results are shown in Fig. 5. When the conventional washing method was used, the increases of the foreign substances of more than 1,000 was found with respect to the low-k layers in comparison with the cases where the oxide layers were washed after the polishing processes thereof. However, the increases of the foreign substances according to the washing method of the present invention were less than 50, which was equivalent to the cases where the oxide layers were polished and washed.

[0017]

[EFFECT OF INVENTION]

A first effect is that the polishing rate can be considerably improved by using the polishing method of the present invention without decomposing the low-k layer in comparison with the case where the low-k layer is polished by the conventional polishing method, resulting in decline in production cost. The polishing process of the low-k can be brought into practice for the first time.

[0018]

A second effect is that the increase of the foreign substances on the low-k layer can be suppressed to a degree equivalent to or less than the increase of the foreign substances on the oxide layer polished and washed, by merely washing the surface of low-k layer, on which the abrasive liquid of the present invention is left without drying the abrasive liquid, using the conventional washing apparatus, washing liquid and washing method as they stand.

[0019]

by obtaining these effects, it is possible to suppress a deterioration of a yield rate of semiconductor devices, which is involved when the low-k layer is planarized, resulting in decline in production cost, being brought into practice.

[BRIEF EXPLANATIONS OF DRAWINGS]

[Fig. 1]

This drawing is a side view of a CMP apparatus which is concerned with a prior art and an embodiment of the present invention.

[Fig. 2]

This drawing is a perspective view of a washing apparatus using a chemical liquid, which is concerned with the prior art and the embodiment of the present invention.

[Fig. 3]

This drawing is a perspective view of another washing apparatus using a pure water, which is concerned with the prior

art and the embodiment of the present invention.

[Fig. 4]

This drawing is a comparative view of polishing rates of polished layers which are concerned with the prior art and the embodiment of the present invention.

[Fig. 5]

This drawing is a comparative view of foreign matters left on the polished layers which are concerned with the prior art and the embodiment of the present invention.

[Explanation Of References]

11: Abrasive Table

12: Abrasive Pad

13: Carrier

14: Wafer-Holding Pad

15: Nozzle

16: Wafer

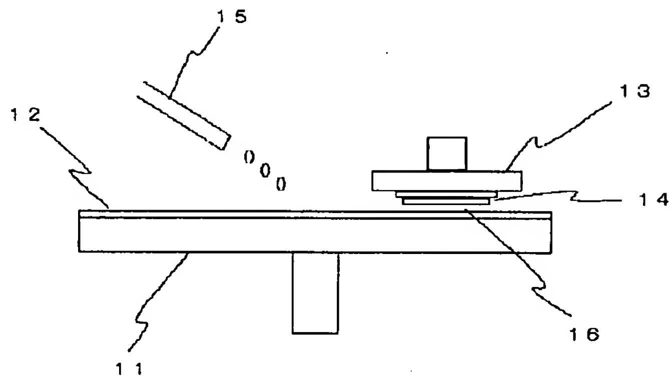
21: Brush

22: Nozzle

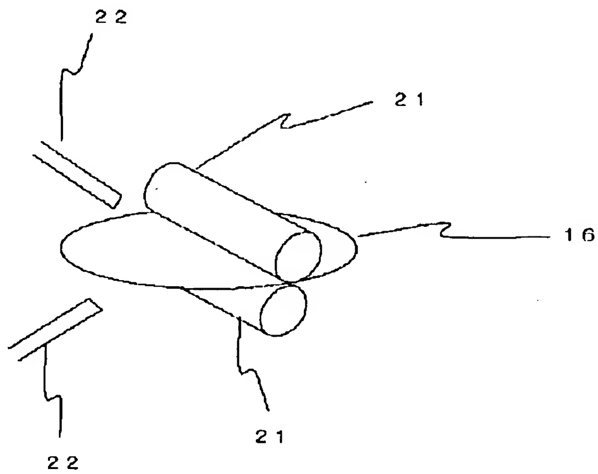
31: Wafer-Washing Table

32: Nozzle

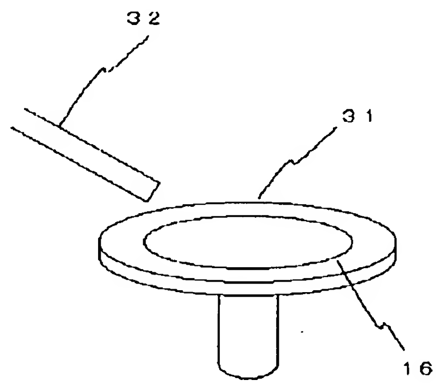
【書類名】　図面
[DOCUMENT NAME]　DRAWINGS
【図１】
[Fig. 1]



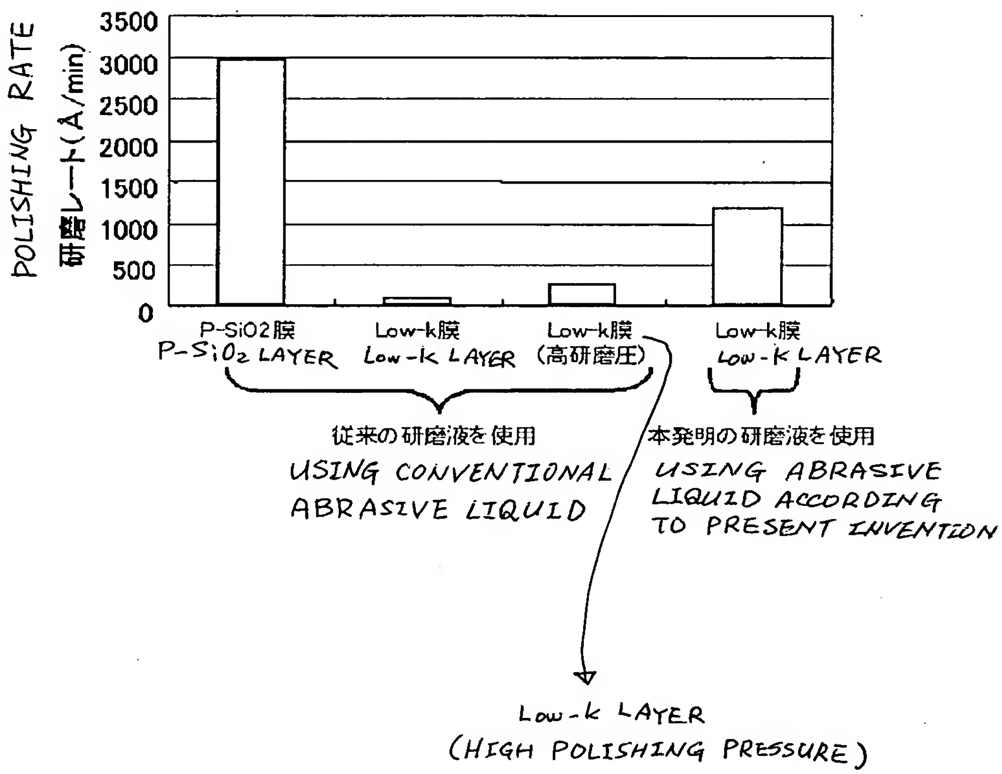
【図２】
[Fig. 2]



【図３】
[Fig. 3]



【図４】
〔Fig. 4〕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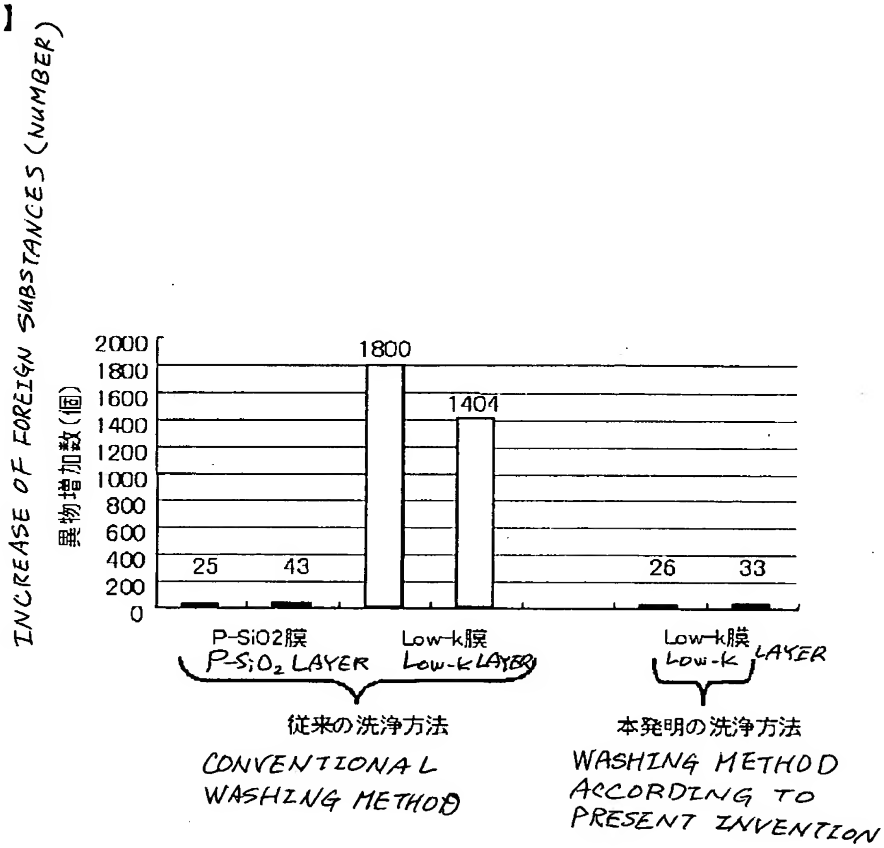
Low-k膜
Low-k LAYER
Low-k膜
(高研磨圧)
Low-k膜
Low-k LAYER
従来の研磨液を使用
USING CONVENTIONAL ABRASIVE LIQUID
本発明の研磨液を使用
USING ABRASIVE LIQUID ACCORDING TO PRESENT INVENTION
Low-k LAYER
(HIGH POLISHING PRESSURE)

【図５】
[Fig.5]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Low-k LAYER
Low-k膜
Low-k LAYER
従来の洗浄方法
CONVENTIONAL WASHING METHOD
本発明の洗浄方法
WASHING METHOD ACCORDING TO PRESENT INVENTION

[DOCUMENT NAME] Abstract

[ABSTRACT]

[Problems] To improve a polishing rate of a low-k layer without decomposing composition of the layer in comparison with a case where the low-k layer is polished with abrasive liquid used to polish an oxide layer, and also to suppress increase of foreign substances on a polished and washed low-k layer to a degree equivalent to or less than increase of foreign substances on a polished and washed oxide layer.

[Solving Means] A chemical mechanical polishing method according to the present invention is characterized in that a low-permittivity layer, including methyl radicals and exhibiting a dielectric constant of less than 3.0, is polished with an abrasive liquid including a hydroxyl group, and also that a silicon wafer is washed after the polishing process, with the abrasive liquid being left on the low-permittivity layer without completely drying a surface of the low-permittivity layer.

[SELECTED DRAWING] NONE